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# DESCRIPTION

# PLASMA TREATMENT APPARATUS

## Technical Field

The present invention relates to a plasma treatment apparatus.

## Background Art

Conventionally, a plasma treatment apparatus 10 as shown in FIG. 6 has been proposed, in which an upper electrode 14 and a lower electrode 16 are opposed in an airtight treatment chamber 12. In this apparatus, when high frequency power is applied to the lower electrode 16 on which an object W is mounted, a glow discharge occurs between the lower electrode 16 and the upper electrode 14. As a result, a processing gas introduced in the treatment chamber 12 is converted to plasma, so that the object W is subjected to plasma treatment.

It is known that, when plasma is generated, a so-called ground return current flows through inner wall surfaces of the treatment chamber 12 because of skin effects, phenomena that are peculiar to high-frequency power. The ground return current then flows from an inner surface wall a of a discharge space 18 of the treatment chamber 12, passes through an inner wall surface b near a baffle plate 22 arranged around the

lower electrode 16, turns to an inner wall surface c of a discharge space 20 below the baffle plate 22, and reaches to a floor surface d. Thereafter, it flows on a surface e of a bellows cover 26 constituting a surface of an elevator mechanism 24, passes through a surface f of the elevator mechanism 24 and returns to a matching device 28.

Conventionally, power of a comparatively low frequency, for example, 380 kHz, was used as high-frequency power to generate plasma. However, in recent years, to produce plasma of higher density, technologies using high-frequency power of a higher frequency, for example, 13.56 MHz or 27.12 MHz, have been developed. In the case where high-frequency power of such a high frequency is used, it is observed that an abnormal discharge occurs in a space in which no problems have occurred conventionally, such as an exhaust space. If such an abnormal discharge phenomenon is left as it is, members may be worn, resulting in decrease of the lifetime of the apparatus, or electrical energy may be reduced, resulting in decrease of the plasma density. In this case, since the plasma treatment is adversely affected, it is necessary to take any measures.

Disclosure of Invention

An object of the present invention is to provide a novel and improved plasma treatment apparatus that

can ensure a ground return current path, so that an abnormal discharge may not occur in the treatment chamber.

The above object is achieved by the following plasma treatment apparatus comprising: an airtight treatment chamber; a lower electrode including a mount portion on which an object is to be mounted, the lower electrode being movable up and down in the treatment chamber; a power supply system to supply high-frequency power to the lower electrode; an elevator mechanism to move the lower electrode up and down; a conductive wall body substantially surrounding the elevator mechanism in close proximity and forming a path reaching to a floor portion of the treatment chamber; and a conductive member provided around the lower electrode and electrically connecting an inner wall of the treatment chamber and the wall body.

With this structure, it is possible to ensure a path of a ground return current, which flows from an inner wall surface of the treatment chamber → a surface of the conductive member → a surface of the wall body → a floor surface of the treatment chamber → the elevator mechanism → the power supply system. The path of this ground return current is shorter than the conventional path described with reference to FIG. 6. In addition, the elevator mechanism and the wall body face each other in close proximity; that is, the space

the surface of the elevator mechanism and the surface of the wall body, where an abnormal discharge is liable to occur, is narrow. Therefore, even if high-frequency power of a high frequency (for example, 10 MHz or higher) is used as a plasma source, no abnormal discharge will occur.

Moreover, in the case where the elevator mechanism is enclosed by the wall body as in the present invention, it is feared that particles remaining near the elevating mechanism may be stirred up by a change in airflow and a change in pressure in the treatment chamber, when the elevating mechanism moves up and down. Therefore, according to an embodiment of the present invention, a through hole or a groove to let escape air remaining in the space between the elevator mechanism and the wall body is formed in the wall body. As a result, the change in airflow and the change in pressure are moderated, thereby suppressing an influence on the process to a minimum.

Furthermore, according to an embodiment of the present invention, the opening to carry in/out the object is provided in the wall body so as not to obstruct operations of carrying in/out the object. In addition, the cover to cover the driving portion of the elevator mechanism is formed on the elevator mechanism in order to prevent dust from adhering to the driving portion of the elevator mechanism and prevent dust

fallen off the elevator mechanism during the operations carrying in/out the object from adhering to the object. In this case, it is preferable that the cover be arranged at least a portion where the object passes, for example, at least between the driving portion and the opening. Further, if the conductive member is constructed as a baffle plate to communicate the treatment chamber and the exhaust path, the apparatus structure can be simplified and the initial cost can be reduced.

Brief Description of Drawings

FIG. 1 is a schematic cross-sectional view showing an etching apparatus to which the present invention is applicable;

FIGS. 2A and 2B are schematic perspective views showing a current conducting member of the etching apparatus shown in FIG. 1;

FIG. 3 is a graph showing a change in plasma density depending on whether the current conducting member is present or not;

FIGS. 4A and 4B are schematic perspective views showing another cylindrical member which can be adopted in the etching apparatus shown in FIG. 1;

FIG. 5 is a schematic perspective view showing another current conducting member which can be adopted in the etching apparatus shown in FIG. 1; and

FIG. 6 is a schematic cross-sectional view for

explaining a conducting path of a ground return current of a conventional plasma treatment apparatus.

Best Mode for Carrying Out of the Invention

A preferred embodiment in which a plasma treatment apparatus of the present invention is applied to a plasma etching apparatus will be described in detail with reference to the accompanying drawings.

(1) Structure of an Etching Apparatus

First, a basic structure of an etching apparatus 100 to which the embodiment is applied will be described with reference to FIGS. 1 and 2. A treatment chamber 102 of the etching apparatus 100 shown in FIG. 1 is formed in a conductive airtight treatment housing 104. The treatment housing 104 is grounded. An inner wall surface of the treatment housing 104 is thinly oxidized. A conductive lower electrode 106 with a mount surface, on which an object such as a semiconductor wafer (hereinafter referred to simply as a wafer) W is to be mounted, is disposed in the treatment chamber 102. An electrostatic chuck 105 to attract and hold the wafer W is formed on the mount surface of the lower electrode 106. An electrically insulating focus ring 107 is provided on the lower electrode 106 so as to surround the mount surface. The lower electrode 106 is supported by an elevating shaft 108 connected to a driving mechanism (not shown) so that it can be moved up and down. The elevating

shaft 108 functions as a feeding rod to supply high-frequency power to the lower electrode 106.

High-frequency power of comparatively high frequency, for example, 27.12 MHz, output from a high-frequency power source 112, is applied to the lower electrode 106 via a matching device 114 and the elevating shaft (feeding rod) 108. Side and bottom portions of the lower electrode 106 are covered by an insulating member 116 made of, for example ceramics. A tubular member 120, which constitutes the elevator mechanism together with the elevating shaft 108, is disposed around the elevating shaft 108. The tubular member 120 is made of an anodic-oxidized conductive material, for example, aluminum. The tubular member 120 is connected to the insulating member 116 and the matching device 114. The tubular member 120 and the insulating member 116 constitute a conducting path of a ground return current described later.

An extensible bellows 118 made of a conductive material, such as stainless steel, is disposed around the elevating shaft 108. The bellows 118 is connected to a conductive member 119 which covers side and bottom portions of the insulating member 116 and a floor portion of the treatment chamber 102, thereby keeping the treatment chamber 102 airtight.

The bellows 118 is covered by a bellows cover 122 made of, for example, anodic-oxidized aluminum.

The bellows cover 122 is supported by the insulating member 116, and prevents dust, such as a reaction product generated during treatment, from adhering to the bellows 118. Therefore, when the bellows 118 is extended and contracted, the wafer W is prevented from contamination, which may occur due to removal of dust adhering to the bellows 118. The bellows 118 and the bellows cover 122 also constitute the conducting path of a grand return current.

A conductive upper electrode 124 is provided in a ceiling portion of the treatment chamber 102, which faces the mount surface of the lower electrode 106. A number of gas delivery holes 124a are formed in the upper electrode 124. A treatment gas supplied from a gas supply source 126, for example, fluorocarbon-based gas, is supplied into the treatment chamber 102 through an open/close valve 128, a flow rate regulating valve 130 and the gas delivery holes 124a. The gas is exhausted from the treatment chamber 120 by a vacuum pump 132 through an exhausting system provided in a bottom portion of the treatment housing 104.

A rotary magnet 134, which generates magnetic field between the upper electrode 124 and the lower electrode 106 to uniformly produce plasma, is disposed outside the treatment housing 104. A wafer carry in/out opening 104a is provided in a lower side wall of the treatment housing 104, so as not to disturb the

arrangement of the rotary magnet 134 and not to form ruggedness which may disturb plasma in a discharge space 142 described later.

A current conducting member 136 characteristic of the present invention will now be described in detail.

As shown in FIGS. 1, 2A and 2B, the current conducting member 136 disposed in the treatment chamber 102 comprises a baffle plate (conductive member) 138 and a cylindrical member (wall body) 140. It constitutes a conducting path of a ground return current. The inside of the treatment chamber 102 is partitioned into a discharge space 142 in which plasma is generated and an exhaust space 144 to which the aforementioned exhausting system is connected. FIG. 2A is a schematic perspective view showing the current conducting member 136. FIG. 2B is a schematic perspective view showing a state in which the current conducting member 136 is separated into the baffle plate 138 and the cylindrical member 140.

The baffle plate 138 is formed of a substantially annular member made of, for example, anodic-oxidized aluminum. It is arranged to surround the lower electrode 106 and electrically connected to an inner side wall of the treatment chamber 102. A plurality of through holes 138a are formed in the baffle plate 138 to allow passage of the gas in the discharge space 142 to the exhaust space 144. The inner diameter of the

baffle plate 138 is set to a dimension that cannot obstruct a vertical motion of the lower electrode 106.

On the other hand, the cylindrical member 140 made of, for example, anodic-oxidized aluminum. It is arranged to surround the lower electrode 106, the bellows 118 and the bellows cover 122. A top portion of the cylindrical member 140 is electrically connected to an inner edge portion of the baffle plate 138, while a bottom portion of the cylindrical member 140 is electrically connected to the floor portion of the treatment chamber 102. With this structure, the side wall of the treatment chamber 102 and the baffle plate 138 are electrically connected, the baffle plate 138 and the cylindrical member 140 are electrically connected, and the cylindrical member 140 and the floor portion of the treatment chamber 102 are electrically connected. The inner diameter of the cylindrical member 140 is set to substantially the same as the inner diameter of the baffle plate 138.

The gap between an inner wall surface of the cylindrical member 140 and the bellows 118 is set to such a distance that an abnormal discharge may not occur between the cylindrical member 140 and the bellows 118 when a ground return current (to be described later) flows. The distance can be calculated from the Paschen's law. According to the Paschen's law, the smaller the product of the distance between

the cylindrical member 140 and the bellows 118 and the pressure in the space therebetween, the higher the voltage required to generate an abnormal discharge between the cylindrical member 140 and the bellows 118. Therefore, if the distance between the cylindrical member 140 and the bellows 118 is set to sufficiently small value, for example, 1 mm or smaller, to make the voltage high, generation of an abnormal discharge can be prevented, even if high-frequency power of a high frequency flows.

An opening 140a to carry in/out the wafer W is provided in a side wall of the cylindrical member 140. The opening 140a is set to a dimension that allows passage of the wafer W and a transfer mechanism 202. It faces the opening 104a of the treatment housing 104.

A process of carrying in/out the wafer W will now be described.

First, the lower electrode 106 is lowered to a predetermined mount position by the driving mechanism not shown. Then, the wafer W placed on the transfer mechanism 202 is moved by the transfer mechanism 202 into the cylindrical member 140 through the opening 104a of the treatment housing 104, the exhaust space 144 in the treatment housing 104 and the opening 140a of the cylindrical member 140, and mounted on the mount surface of the lower electrode 106. Thereafter, the lower electrode 106 is moved up to a predetermined

treatment position and the wafer W is subjected to an etching treatment. After the treatment, in the reverse of the above, the lower electrode 106 is lowered to the mount position, and then the wafer W on the lower electrode 106 is carried out by the transfer mechanism 202 to a transfer chamber 200.

A number of through holes 140b are formed in the side wall of the cylindrical member 140 in order to discharge the gas existing in the space between the bellows 118 and the cylindrical member 140 into the exhaust space 144, when the lower electrode 106 moves down. This structure prevents the pressure in the aforementioned space from increasing when the lower electrode 106 moves down. If the pressure is increased, the gas will be spouted and particles will be raised in the discharge space 142, in which case the wafer W or the discharge space 142 may be contaminated. Such a problem is prevented by the above structure. A groove may be formed instead of the through hole 140b. In this case, the same effect as described above can be obtained.

(2) Structure of Transferring a Ground Return Current

A structure to transfer a ground return current during an etching treatment will be described with reference to FIG. 1. In an etching treatment, a ground return current is caused to flow through an inner wall

surface A of the treatment chamber 102 enclosing the discharge space 142 due to a glow discharge that occurs between the lower electrode 106 and the upper electrode 124 as in the conventional art. Thereafter, in the etching apparatus 100 of this embodiment, the ground return current flows from the inner wall surface A of the treatment chamber 102 to a surface B of the baffle plate 138 on the side of the discharge space 142, since the baffle plate 138 is electrically connected to the inner side wall of the treatment chamber 102. Then, the ground return current from the surface B of the baffle plate 138 passes through an inner wall surface C of the cylindrical member 140 without entering the exhaust space 144 because of skin effects, and flows to a floor surface D of the treatment chamber 102. With this structure, since the ground return current does not enter the exhaust space 144, no electric field is generated in the exhaust space 144. Thus, even if high-frequency power of a high frequency is used, an abnormal discharge will not occur in the exhaust space 144. As a result, the inner wall surface of the treatment chamber 102, which is exposed in the exhaust space 144, will not wear, so that there will be no loss of high-frequency energy. Further, since the baffle plate 138 defining the discharge space 142 is electrically connected to the grounded treatment housing 104, the ground potential in the discharge

space 142 is kept constant, with the result that uniform plasma can be generated. The ground return current flows from the floor surface D of the treatment chamber 102 through an outer wall surface E of the bellows 118, an outer wall surface Ea of the bellows cover 122, the insulating member 116 (Fa) and the tubular member 120 (F), and returns to the matching device 114. When this structure is adopted, since the cylindrical member 140 is arranged near the bellows 118, the inductance can be smaller than that in a case of the conventional apparatus shown in FIG. 6, in which the ground return current passes through the exhaust space 20 and returns to the matching device 28, as is understood from the following equation (1). As a result, since the potential difference between the input side and the output side of the matching device 114 can be reduced, occurrence of an abnormal discharge can be further prevented.

$$L=(\mu_0 \mu / \pi)\, \iota\, \mathrm{In}(d/R) \qquad \cdots(1).$$

In the equation (1), L denotes an inductance, $\mu_0$ denotes a constant, $\mu$ denotes a relative permeability of the gas in the treatment housing 104, $\iota$ denotes a length of a path of the ground return current, d denotes a distance between the bellows 118 and the cylindrical member 140, and R denotes a thickness of the treatment housing 104.

(3) Example of the Embodiment and Comparative Example

An example of the above embodiment and a comparative example thereof will be described below with reference to FIG. 3. Plasma densities in the discharge spaces 18 and 142 were measured in the example using the etching apparatus 100 shown in FIG. 1, and in the comparative example using the conventional apparatus 10 shown in FIG. 6. Ar was supplied to the discharge spaces 18 and 142 at a flow rate of 200 sccm. The spaces 18 and 142 were kept at a pressure of 40 mTorr. High-frequency power of 13.56 MHz and 27.12 MHz was respectively applied to the lower electrodes 16 and 106.

As a result, as shown in FIG. 3, when the high-frequency power of 27.12 MH was employed, the plasma density was higher in the case where the current conducting member 136 was used than in the case where it was not used. When the current conducting member 136 was used, the plasma density was increased in proportion to the power. Based on these results, it is understood that the occurrence of an abnormal discharge is prevented and a high-frequency energy loss is not easily caused. On the other hand, when the high-frequency power of 13.56 MHz was used, there was not much difference between the cases where the current conducting member 136 was used and not used.

Therefore, it is understood that the etching apparatus 100 is particularly effective in the case where high-frequency power of a frequency higher than 13.56 MHz, which can generate high-density plasma, is employed.

As has been described above, according to this embodiment, an abnormal discharge within the treatment chamber 102 can be prevented, with the result that the lifetime of the plasma processing apparatus can be increased. Further, since there is no loss of high-frequency energy, plasma of a high density can be generated. Furthermore, since the ground potential in the plasma generating space can be kept constant, uniform plasma can be generated.

The present invention is not limited to the above structure. Various modifications and revisions will be obvious to a person skilled in the art in the category of technical ideas described in the claims. It is considered that such modifications and revisions fall under the technical scope of the present invention. For example, in the above embodiment, the cylindrical member 140 surrounding the entire circumference of the bellows 118 is described. However, the present invention is not limited to this structure. For example, a cylindrical member 200 a part of which is cut off as shown in FIG. 4A or a cylindrical member 300 a part of which is cut and the lower opening of which is narrowed as shown in FIG. 4B may be used. In this

case also, the present invention can be worked. Further, in the above embodiment, the structure in which the inner wall of the treatment chamber 102 and the cylindrical member 140 are connected by the baffle plate 138 is described. However, the present invention is not limited to this structure. For example, as shown in FIG. 5, a structure of connecting the inner wall of the treatment chamber 102 and the cylindrical member 130 by a conductive member 400 may be employed. The present invention can also be worked by this structure. Furthermore, in the above embodiment, the baffle plate 138 has a substantially annular shape and the cylindrical member 140 has a substantially cylindrical shape. However, the present invention is not limited to this structure. The shapes of the wall body 140 or the conductive member 138 may be suitably changed in accordance with the shape of the treatment chamber 102 and the arrangement or the shapes of the lower electrode 106 and the elevating mechanism. In this case, the present invention can also be worked. Further, in the above embodiment, a structure in which the bellows cover 122 is attached to the insulating member 116 is described. However, the present invention is not limited to this structure. For example, the bellows cover 122 may be attached to the tubular member 120. In this case, the present invention can also be worked.